

# **Recommended Sea Level Rise Scenarios for Delaware**

In support of  
**Delaware Department of Natural Resources and  
Environmental Control (DNREC)  
Sea Level Rise Policy**

*December, 2009*

Developed by  
**DNREC Sea Level Rise Technical Workgroup**

Coordinated by  
**Delaware Coastal Programs Section of DNREC**

## **Introduction**

One of the most significant impacts of global climate change for Delaware will be changes to and losses of the State's coastal resources from sea level rise (SLR). These changes could have major economic and social consequences for a wide range of public and private interests through shoreline erosion, inundation of wetlands and uplands, changes to habitat and damage to public infrastructure.

To proactively address the potential consequences of future sea level rise, the Delaware Department of Natural Resources and Environmental Control (DNREC) is developing a Sea Level Rise Policy that will require the consideration of the effects of sea level rise for all DNREC activities (Appendix I). One of the most critical factors that form the scientific basis for the future policy decisions is an accurate estimate of the projected sea level rise range for Delaware. A DNREC Technical Workgroup comprised of scientists from DNREC, University of Delaware, Partnership for the Delaware Estuary and the Center for the Inland Bays, has been formed to evaluate the known scientific basis and provide the State with sea level rise scenarios up to the year 2100 (Appendix II). Due to the complex nature of global climate change and the numerous factors that affect sea level rise and the significant differences among coastal areas, the Technical Workgroup has chosen to base the Delaware sea level rise scenarios on published expert summaries of existing data and predictions from national and international panels and federal agencies rather than those of individual researchers.

This paper summarizes the statements, guidelines and policies of federal agencies in their projections for global sea level rise (GSLR). From this collection of information and data on the region's historic local sea level rise (LSLR) rates the Technical Workgroup has developed SLR scenarios to use for Delaware up to the year 2100.

### **Technical Workgroup Recommendation**

***Based on the information from the Intergovernmental Panel on Climate Change Assessment Report 4 (IPCC AR-4) and Climate Change Science Program Synthesis and Assessment Product 4.1 (CCSP SAP 4.1) reports and the recommendations and guidelines of federal agencies (described below), the Department of Natural resources and Environmental Control Sea level Rise Technical Workgroup proposes the use of three planning scenarios for local sea level rise: 0.5, 1.0, and 1.5 meters. It is the intention of the DNREC SLR Technical Workgroup that these SLR scenarios be reviewed and updated periodically as new information and federal guidelines become available.***

## **Historic Sea Level Rise for the Delaware Region**

There are eleven tide stations from Philadelphia, PA south to Ocean City, MD and from Baltimore, MD east to Atlantic City, NJ that are maintained by the National Oceanic and Atmospheric

Administration (NOAA; Table 1.). NOAA statistically analyzed data from each of these stations and determined annual rates of sea level change for the period of record (NOAA, 2009a). These are reported as rates of LSLR. Eight of these tide stations have the requisite amount of data (at least 40 to 50 years) for estimating changes in sea level as recommended by Intergovernmental Oceanographic Commission (IOC 1985) and Climate Change Science Program (CCSP 2009). The average LSLR rate for these eight stations is 3.36 mm/yr with Philadelphia, PA and Atlantic City, NJ having the lowest (2.79 mm/yr) and highest (3.99 mm/yr) rates, respectively. The two Delaware stations at Lewes and Reedy Point have rates of 3.20 mm/yr and 3.46 mm/yr, respectively, for an average rate of 3.33 mm/yr (NOAA 2009a). ***Based on the Delaware and nearby regional data of tide stations with more than 50 yrs of data, the average historic local sea level rise (LSLR) for Delaware is 3.35 mm/yr (0.35 m/100 yr or 1.1 ft/100 yr).***

GSLR or eustatic SLR is the estimated rise in sea level for the planet due to the reduction in volume (melting) of the ice caps, ice fields, and mountain glaciers in addition to the thermal expansion of ocean water (USGS, 2000). The historic GSLR rate for the last 100 years used by the Intergovernmental Panel on Climate Change (IPCC, 2007) is 1.7 mm/yr. The difference between the GSLR and LSLR rates is primarily due to land subsidence from tectonic subsidence (glacio-isostatic adjustment resulting from melting of late Pleistocene glaciers, and/or regional tectonic subsidence of the Atlantic coast) and possibly sediment compaction (Davis, 1987). Due to the long time-scale of tectonic changes, it is reasonable to assume that the difference (+1.65 mm/yr) between rates of GSLR (1.7 mm/yr) and LSLR (3.35 mm/yr) can be considered constant for at least the next 100 years. ***Therefore, to compute the LSLR rates for Delaware, a value of 1.65 mm/yr must be added to estimates of GSLR rates. This results in an addition of 0.15 meters to any predicted GSLR projections for the year 2100.***

Table 1. NOAA SLR analysis (NOAA, 2009a).

Location	SLR (mm/yr)	95% Confidence (mm)	Period of Record
Reedy Point, DE	3.46	0.66	1956-2006*
Lewes, DE	3.20	0.28	1919-2006*
Annapolis, MD	3.44	0.23	1928-2006*
Atlantic City, NJ	3.99	0.18	1911-2006*
Baltimore, MD	3.08	0.15	1902-2006*
Cambridge MD	3.48	0.39	1943-2006*
Cape May, NJ	4.06	0.74	1965-2006
Chesapeake City, MD	3.78	1.56	1972-2006
Ocean City, MD	5.48	1.67	1975-2006
Philadelphia, PA	2.79	0.21	1900-2006*
Solomons Island, MD	3.41	0.29	1937-2006*

\*  $\geq 50$  years

## **Sea Level Rise Predictions from the Intergovernmental Panel on Climate Change**

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on current and predicted states of climate change and the potential environmental and socio-economic consequences. The IPCC issued new predictions in 2007 (IPCC, 2007) that were lower than the IPCC (2001) predictions. However, due to the uncertainty of the models at the time, the IPCC (2007) predictions did not include contributions to GSLR from melting of the ice caps and glaciers, primarily the Western Antarctica Ice Sheet and the Greenland Ice Sheet. IPCC (2007) gives rates of GLSR ranging from 0.18 to 0.59 meters by the year 2100. These values are based on different scenarios for greenhouse gas emissions and do not include the possibility of accelerated melting of ice sheets.

***When the LSLR correction is included in the predictions, the values range from 0.33 to 0.74 meters by 2100 for Delaware.***

Since the publication of IPCC (2007), new technologies have enabled better estimates of ice melt and the models have been adapted to include this information. The latest predictions used by several federal agencies and other organizations incorporate ice-sheet melting in their estimates and suggest higher rates for GSLR than in IPCC (2007). The next IPCC report will be completed in 2013.

## **Current Predictions and Policies of United States Agencies**

### **United States Army Corps of Engineers (USACE)**

The USACE Circular 1165-2-211, entitled “*Incorporating Sea-Level Change Considerations in Civil Works Programs*”, released July 1, 2009 (USACE, 2009), requires the incorporation of sea level change projections into planning, engineering design, construction, and operating projects. The USACE considers three scenarios based on project sensitivity relative to human health and safety, economic costs and benefits, environmental impacts, and other social effects. The values for determining SLR over the life of a project are developed using equations found in the National Research Council’s 1987 report *Responding to Changes in Sea Level: Engineering Implications* (NRC, 1987). However for the lowest sensitivity scenario the USACE uses an extrapolation of the existing rate of LSLR for the area of study.

***The 2100 LSLR values using the USACE method and Delaware LSLR correction are:***

<b><i>Low (existing LSLR rate)*</i></b>	<b><i>0.31 m</i></b>	<b><i>*For comparison the NRC-I value is 0.60 m</i></b>
<b><i>Intermediate (NRC-II)</i></b>	<b><i>1.08 m</i></b>	
<b><i>High (NRC-III)</i></b>	<b><i>1.55 m</i></b>	

## United States Climate Change Science Program (CCSP)

The CCSP report entitled “*Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region*” (CCSP, 2009) recommends using higher GSLR values than those in IPCC (2007) because of the exclusion of the ice-melt contributions in IPCC (2007). The report states: "Therefore, thoughtful precaution suggest that a global sea-level rise of 1 m to the year 2100 should be considered for future planning and policy discussions." (CCSP 2009, p. 20). ***Correcting the 1 meter GSLR for the local factors results in a value of 1.15 meters of local sea level rise by 2100.***

A separate report by the CCSP Subcommittee on Global Change Research includes the statement: "Although no ice-sheet model is currently capable of capturing the glacier speedups in Antarctica or Greenland that have been observed over the last decade, including these processes in models will very likely show that IPCC 2007 projected sea level rises for the end of the 21<sup>st</sup> century are too low." (CCSP 2008, p. 12)

## National Oceanic and Atmospheric Administration

NOAA has not announced a formal value to use for sea level rise but in the transcript entitled “*NOAA Response to Congressional Questions Regarding Climate Change*” (NOAA, 2009b), NOAA officials state that "The models used to project sea level rise reflect a fairly robust scientific understanding of the contributions of thermal expansion and glacier melting to sea level rise. The complex processes that determine past and potential contributions to sea level rise from changes in ice sheets, however, are less well understood. The scientific literature used in preparing the 2007 assessment by IPCC reflected the inability of the scientific community at the time to quantify the contributions to sea level rise due to changes in ice sheet dynamics, and thus projected rise in the world's oceans of between 8 inches [0.20 m] and two feet [0.61 m] by the end of this century. More recent research has provided additional insights into the potential contributions to sea level rise from the accelerated flow of ice sheets to the sea and to estimate sea level based on the observed relationship between sea level and temperature. Estimates of sea level rise based on these new scientific insights exceed those of the IPCC with the average estimates for sea level rise under higher emission scenarios at between 3 and 4 feet [0.91 m and 1.22 m]." (NOAA, 2009b). ***Correcting the GSLR for the local factors results in between 1.06 and 1.37 meters of local sea level rise would be expected for Delaware by 2100.***

## National Aeronautical and Space Administration (NASA)

The 2009 report entitled “*The Copenhagen Diagnosis: Updating the World on the Latest Climate Science*” (CCRC, 2009) includes two NASA authors among the 26 contributors. This report examines new data that was not available for use in IPCC (2007). NASA is referencing this report on their website (NASA, 2009), the report states:

- Satellite and direct measurements now demonstrate that both the Greenland and Antarctic ice-sheets are losing mass and contributing to sea level rise at an increasing rate.
- Arctic sea-ice has melted far beyond the expectations of climate models. For example, the area of summer sea-ice melt during 2007-2009 was about 40% greater than the average projection from the 2007 IPCC Fourth Assessment Report.
- Sea level has risen more than 5 centimeters over the past 15 years, about 80% higher than IPCC projections from 2001. Accounting for ice-sheets and glaciers, global sea-level rise may exceed 1 meter by 2100, with a rise of up to 2 meters considered an upper limit by this time. This is much higher than previously projected by the IPCC. Furthermore, beyond 2100, sea level rise of several meters must be expected over the next few centuries.

Using the estimates from the preceding paragraph and factoring in the LSLR correction for Delaware, ***LSLR in Delaware may exceed 1.15 m with a rise of up to 2.15 m as an upper limit by 2100.***

### **Unites States Environmental Protections Agency (USEPA)**

The USEPA currently references IPCC (2007) for GSLR, however they also recognize the uncertainty of the predictions due to ice melt. They acknowledge the Western Antarctica Ice Sheet contains enough ice to raise global sea level by 5-6 meters and the Greenland Ice Sheet contains enough ice to raise global sea level by 7 meters (USEPA, 2009). The USEPA was also a major contributor to the CCSP (2009) report described above.

### **DNREC Scenarios**

Based on the information in IPCC (2007) and CCSP (2009) and the recommendations and guidelines of federal agencies, the ***Workgroup proposes to use LSLR scenarios for Delaware of 0.5, 1.0, and 1.5 meters by the year 2100.*** These values represent the minimum, intermediate, and maximum rates expected based on the compilation of currently available information. The workgroup suggests that DNREC consider a project's sensitivity to sea level rise in all future efforts. The sensitivity to be determined by a process of vulnerability assessments to be outlined by DNREC within 12 to 18 months. The sensitivity analysis should be based on the longevity, risk and socio-economic value of the project. Low sensitivity projects should consider a minimum LSLR of 0.5 meters by 2100 for all planning, design and regulation efforts. High sensitivity projects should consider 1.5 meters of LSLR by 2100. Interim LSLR values for different project sensitivities of shorter term projects can be determined by using the graph in Figure 1. These values are based on the National Research Council (NRC, 1987) model used by the US Army Corps of Engineers (USACE, 2009). The stable projection is an extrapolation of the current rate of LSLR for reference.

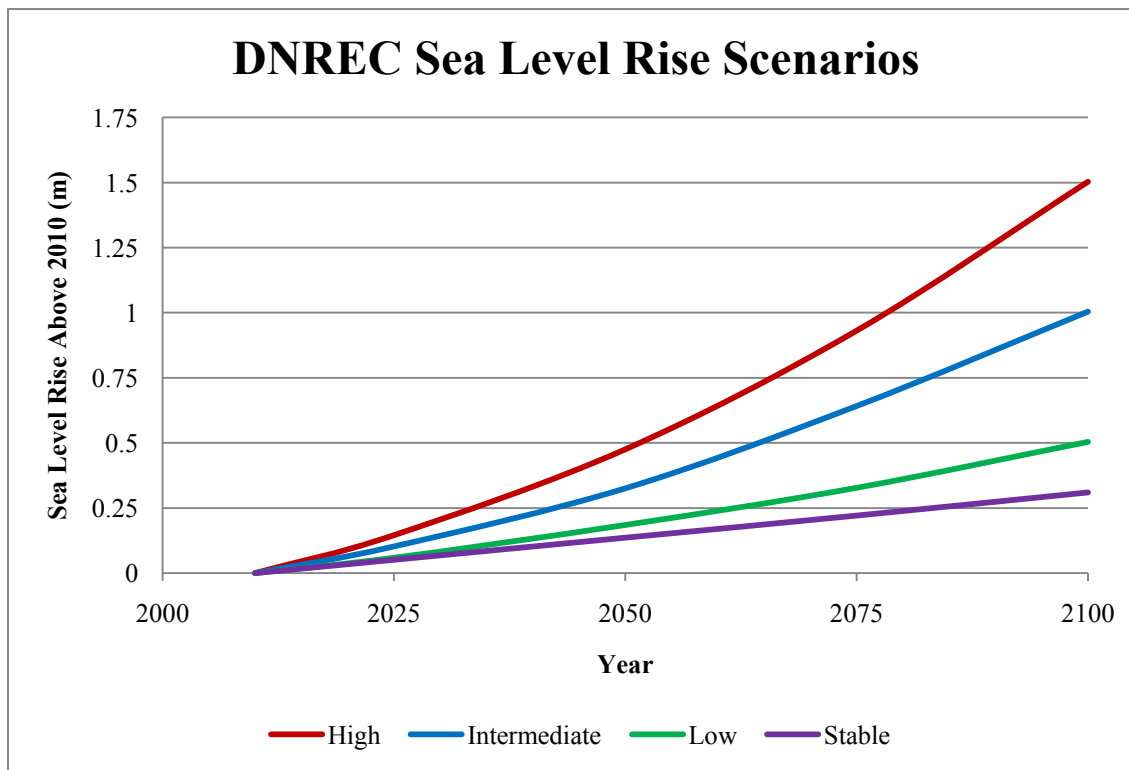


Figure 1. Proposed DNREC SLR scenarios 2010-2100.

*It is the intention of the DNREC SLR Technical Workgroup that these SLR scenarios be reviewed and update periodically as new information and federal guidelines become available.*

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## **Appendix I**

### **Draft DNREC Sea Level Rise Policy**

Department of Natural Resources & Environmental Control  
Administrative Policies and Provisions

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Subject: D-1306 – Sea Level Rise Adaptation

Section: D-1300 – Resources Programs Management

Issued: 1/27/2010

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Page: 1 of 2

Procedure:

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### **Background**

Delaware experiences inundation from the sea on a regular basis. Coastal Storms routinely cause flooding through the effects of storm surge and heavy rainfall. The resulting inundation causes significant social and economic impacts in the short-term. Future inundation impacts will be further exacerbated by local changes in sea level.

Documented data has shown that Sea level has increased in Delaware by more than one foot over the past century. The conclusion of the Intergovernmental Panel of Climate Change is that the rate of sea level rise will increase over the next century. While evidence has shown that the sea level has changed dramatically over the course of time, the coastline can no longer adapt naturally as it has in the past due to human development and alterations of the landscape.

Sea level rise will cause increased inundation and shoreline erosion; increased tidal surge, flooding from severe weather events; accelerate saltwater contamination of ground water and surface water supplies, elevate water tables, and expedite loss of critical habitats.

Development in Delaware's coastal zone that does not account for increasing inundation levels puts homes, businesses and infrastructure at risk resulting in human hardship and higher cost to government for response and recovery. Additionally, marshes and other critical low-lying habitats may also be at risk due to the inability to naturally migrate landward with rising sea levels. A policy that addresses the effects of inundation by adapting to sea level rise will make Delaware more resilient to short-term storm events and long term sea level rise.

## **Policy**

It is the position of the Department of Natural Resources & Environmental Control (DNREC) that sea level rise is currently occurring and will continue to occur at an accelerated rate due to global climate change. Further, it is the policy of DNREC to proactively consider and plan for the potential effects of coastal inundation department-wide using scenarios based on the best available science.

As such:

1. All DNREC staff when representing the Department shall communicate the Department's policy internally and externally.
2. All DNREC programs shall consider the potential effect of coastal inundation in project planning, engineering, design, and review, as well as land acquisition, management, and restoration.
3. All DNREC programs shall conduct a vulnerability assessment for all DNREC holdings and assets to identify risks from inundation and develop plans to increase resiliency and adaptability. The process and timing of these actions will be determined by DNREC in a developed within 12 to 18 months of the signing of this policy.
4. All DNREC programs shall consider project alternatives that avoid siting buildings and infrastructure within areas that are vulnerable to inundation. If avoidance is not practicable, project design must address the consequences of inundation.
5. All DNREC programs shall use the following range of sea level rise scenarios, appropriate to the project's longevity and nature. Projects of a longer expected life or more critical nature should practice precautionary principles and use a more protective sea level rise scenario.

As of February 1, 2010; the following scenario(s)\* shall be used:

0.5 meters by 2100 for low sensitivity projects  
1.0 meters by 2100 for medium sensitivity projects  
1.5 meters by 2100 for high sensitivity projects

\*These values shall be adjusted as the IPCC and other peer reviewed publications produce updated scenarios and modeling techniques.



Secretary, Department of Natural Resources and Environmental Control  
Date 1/27/10

## **Appendix II**

### **DNREC Sea Level Rise Technical Workgroup Members**

Mr. Chris Bason, Science & Technical Coordinator, Center for the Inland Bays  
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